ARTICLE 7

PROCEDURES FOR DIAPHRAGMS

7.0 INTRODUCTION

The diaphragm is the horizontal subsystem that distributes lateral load to the vertical subsystems (walls and frames) and that provides lateral support for walls and parapets.

7.1 DIAPHRAGMS

Diaphragms are treated as horizontal beams. The floor (or roof), which is analogous to the web of a wide-flange beam, is assumed to carry the shear; the edge of the floor (or roof) or a spandrel, which is analogous to the flange, is assumed to carry the flexural stress.

7.1.1 PLAN IRREGULARITIES: There is significant tensile capacity at re-entrant corners or other locations of plan irregularities.

For buildings designed and constructed in accordance with the 1989 or later editions of Part 2, Title 24, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the diaphragm in the vicinity of corners. Evaluate the chord/collector requirements at the re-entrant corners and other locations of plan irregularities by applying the maximum of the diaphragm force and the calculated story force to a model of the isolated diaphragm. All elements that can contribute to the tensile capacity at the re-entrant corner may be included with appropriate consideration given to gravity load stresses. Conforming buildings which fail this check shall be placed in SPC 4.

7.1.2 CROSS TIES: There are continuous cross ties between diaphragm chords.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the adequacy of the path for wall anchorage forces into the diaphragm. A cross tie is a beam or girder that spans across the width of the diaphragm, accumulates the wall loads, and transfers them, over the full depth of the diaphragms, into the next bay and on to the nearest shear wall or frame. Calculate the wall anchorage forces according to Sec. 2.4.5, and check that these forces can be developed, element by element, in the diaphragm.

7.1.3 REINFORCING AT OPENINGS: There is reinforcing around all diaphragm openings larger than 50 percent of the building width in either major plan dimension.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the diaphragm in the vicinity of the openings. Check the adequacy of the diaphragm to transfer stresses around the opening.

7.1.4 OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls constitute less than 25 percent of the wall length, and the available length appears sufficient.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the length of diaphragm needed to transfer shear to the wall or frame and to provide lateral support for the wall or frame.

Procedure for diaphragm shear: Verify that there is a path of forces and sufficient strength to deliver the diaphragm shear to the shear wall. The diaphragm shear is the demand.

Procedure for lateral support of the wall: Treat the wall as a portion of the building using F_p as the demand.

7.1.5 OPENINGS AT BRACED FRAMES: Diaphragm openings immediately adjacent to the braced frames extend less than 25 percent of the length of the bracing.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is similar to that described above for openings at shear walls.

Procedure for diaphragm shear: Verify that there is a path of forces and sufficient strength to deliver the diaphragm shear to the braced frame. The diaphragm shear is the seismic demand.

Procedure for lateral support of the frame: Treat the frame as a portion of the building using F_p as the demand.

7.1.6 OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry walls are no more than 8 feet long.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is similar to that described above for openings at shear walls.

Procedure for diaphragm shear: Verify that there is a path of forces and sufficient strength to deliver the diaphragm shear to the shear wall. The diaphragm shear is the demand.

Procedure for lateral support of the wall: Treat the wall as a portion of the building using F_p as the demand.

7.2 WOOD DIAPHRAGMS

7.2.1 SHEATHING: None of the diaphragms consist of straight sheathing or have span/depth ratios greater than 2 to 1.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the diaphragm. Analyze the wood diaphragm using the procedure given in Chapter 9 of the 1994 *NEHRP Recommended Provisions*.

7.2.2 SPANS: All diaphragms with spans greater than 24 feet have plywood or diagonal sheathing. Structures in Building Type 2 may have rod-braced systems.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength and stiffness of the diaphragm. Evaluate the diaphragm stresses using the procedure given in Chapter 9 of the 1994 *NEHRP Recommended Provisions*. Also evaluate the deflections. A maximum displacement of 3 inches shall be acceptable. For horizontal bracing systems see Section. 7.5.

7.2.3 UNBLOCKED DIAPHRAGMS: Unblocked wood panel diaphragms consist of horizontal spans of less than 40 feet and have span/depth ratios less than or equal to 3 to 1.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the diaphragm. Analyze the diaphragm using the 1994 *NEHRP Recommended Provisions* requirements for unblocked diaphragms.

7.2.4 SPAN/DEPTH RATIO: If the span/depth ratios of wood diaphragms are greater than 3 to 1, there are nonstructural walls connected to all diaphragm levels at less than 40-foot spacing.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the stiffness of the diaphragm. Analyze the wood diaphragm using the procedures given in Chapter 9 of the 1994 *NEHRP Recommended Provisions*.

7.2.5 DIAPHRAGM CONTINUITY: None of the diaphragms are composed of split-level floors or, in wood commercial or industrial buildings, have expansion joints.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the diaphragm. Evaluate the building with proper recognition of the effects of the discontinuities.

7.2.6 CHORD CONTINUITY: All chord elements are continuous, regardless of changes in roof elevation.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is the lack of a chord. Report the lack of a chord as a deficiency.

7.3 METAL DECK DIAPHRAGMS

Allowable values of metal deck diaphragms may be obtained from manufactures approved data. The evaluator shall consider conditions that can weaken the diaphragm (i.e., troughs, gutters, and recesses that have the effect of reducing the system to the bare deck or of creating a joint).

7.3.1 DECK TOPPING: All metal deck roofs have a reinforced concrete topping slab.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the diaphragm. Evaluate the bare metal deck diaphragm using the procedure given in the 1994 *NEHRP Recommended Provisions* requirements.

7.3.2 UNTOPPED DIAPHRAGMS: Untopped metal deck diaphragms consist of horizontal spans of less than 40 feet and have span/depth ratios less than or equal to 3 to 1.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the diaphragm. Analyze the diaphragm using the procedure given in the 1994 *NEHRP Recommended Provisions* requirements.

7.4 PRECAST CONCRETE DIAPHRAGMS

Evaluation of precast concrete diaphragms and the connections between precast elements, shall consider eccentricities, adequacy of welds, and length of embedded bars. If a topping slab is provided, it shall be assumed to resist all of the shear.

7.4.1 TOPPING SLAB: Precast concrete diaphragm elements are interconnected by a reinforced concrete topping slab.

The deficiency is in the ability to transfer shear from one element to another. Check the slab element interconnection and check the lateral load capacity of the vertical elements that resist horizontal force. Where the capacity of the diaphragm is less than 150 percent of the sum of the load capacities of the vertical elements and where connections can allow the diaphragm to fail in a brittle manner, the R values used in computing the seismic demand shall be consistent with those for brittle systems (not to exceed $R = 2$). Conforming buildings without a reinforced concrete topping slab shall be placed in SPC 4.

7.4.2 CONTINUITY OF TOPPING SLAB: The topping slab continues uninterrupted through the interior walls and into the exterior walls or is provided with dowels with a total area equal to the topping slab reinforcing.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is the abrupt loss of strength where the topping slab is interrupted. Evaluate the tension and shear demand due to diaphragm forces including collector requirements, perpendicular-to-wall loads, or chord forces at re-entrant corners.

7.5 HORIZONTAL BRACING

7.5.1 HORIZONTAL BRACING. Horizontal bracing forms a complete system of adequate capacity.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is an incomplete or inadequate horizontal bracing system. Evaluate the horizontal bracing system for completeness of the system and its ability to gather all tributary forces and deliver them to the walls or frames.

7.6 OTHER SYSTEMS

7.6.1 OTHER SYSTEMS: The diaphragm systems does not include thin planks, and/or toppings of gypsum.

The deficiency is inadequate capacity of the diaphragm. Conforming buildings that with this system shall be placed in SPC 4.